ZAMS ROTATIONAL VELOCITIES OF Be STARS

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Abstract. We show that Be stars belong to a high velocity tail of a single B-type star rotational velocity distribution in the main sequence (MS). We studied 127 galactic field Be stars and obtained their true equatorial velocity at the ZAMS using models of stellar evolution with rotation. There is a sharp mass-dependent cut in the ZAMS under which there is no Be star. Velocities above this cut follow a Gaussian-tail distribution. B stars with ZAMS rotational velocities lower than the cut probably cannot become Be.

1 Motivation and Method

There is a long-lasting debate whether Be stars belong to a high velocity end of a single distribution suited to all MS B stars, or they form a stellar group with a separate high-velocity distribution. To obtain answer elements to this question, we corrected the $V \sin i$ for gravitational darkening effects (Frémat et al. 2005), calculated the inclination angle i and derived masses and ages of 127 program Be stars using models of stellar evolution with rotation (Meynet & Maeder 2000, Zorec et al. 2005). To derive the respective ZAMS true equatorial velocities we have taken into account four main phenomena determining the variation of the surface rotation with age (Meynet & Maeder 2000): 1) the equatorial radius-dependent changes; 2) variations due to angular momentum-loss through mass-loss events; 3) variations carried by internal density distribution changes with age and rotation, which affect the stellar inertial momentum; 4) meridional circulation and other hydrodynamical instabilities that produce internal angular momentum redistribution with time scales of the order of $\tau_{\rm HK}/\eta$, where $\tau_{\rm HK}$ is the Kelvin-Helmholtz time and $\eta \sim 0.9$ is the ratio of centrifugal to gravitational acceleration.

We note that $V_{\rm ZAMS}$ is the equatorial velocity the star acquires after its rapid initial short-lasting re-arrangement of the internal angular velocity law $\Omega(r)$. This re-arrangements last no more than 1 to 2% of the stellar MS life (Denissenkov et al. 1999, Meynet & Maeder 2000) and transforms an initial entirely rigid rotation into another differential one where the stellar core has a faster angular velocity than the equator.

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2 Results and Conclusion

The transformation of individual $V \sin i$ parameters into $V_{\rm ZAMS}$ is shown in Fig. 1a. The most striking feature in this figure is the neat cut depicted by the regression line obtained from the $V_{\rm min}$ in each mass-interval. According to this finding, no Be star is seen below the cutting line. This indicates that stars need an initial velocity $V_{\rm ZAMS} \stackrel{>}{\sim} V_{\rm min}$ in order to become Be at any moment in the MS evolutionary phase. In each mass-interval we divided the $V_{\rm ZAMS}$ by the corresponding $V_{\rm min}$ and formed the global histogram shown in Fig. 1b. The fit that better describes the distribution obtained is a Gaussian tail. We note that under the histogram there must be roughly 17% of stars out of the whole MS B-type star population. More than 80% of B-type stars must then be gathered into the $V_{\rm ZAMS}/V_{\rm min} \stackrel{<}{\sim} 1$ interval. It may then happen that Be stars do not form a separate distribution, but possibly a Gaussian-like tail of a more general distribution of rotational velocities that encompasses the whole MS B-type star population.

We note that some B stars without emission lines, of which a non negligible proportion is in the lower mass-extreme ($M < 7 M_{\odot}$) is represented by Bn stars, which distribute over both velocity intervals. Bn stars with $V_{\rm ZAMS} < V_{\rm min}$ might then never become Be, while those with $V_{\rm ZAMS} > V_{\rm min}$ could probably do.

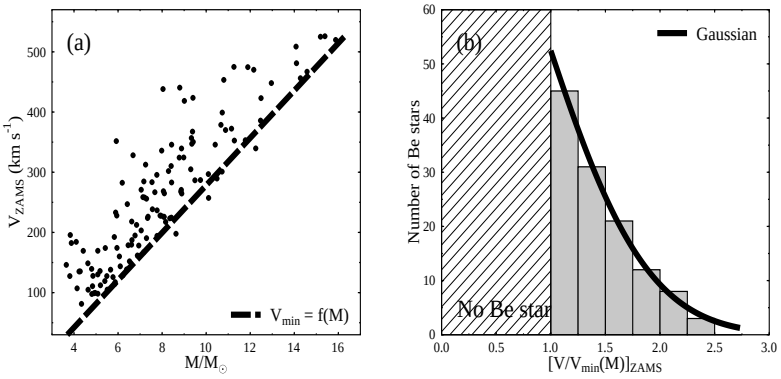

Fig. 1. (a): Distribution of true rotational velocities at ZAMS of the studied galactic Be stars. There is a clear cut under which there is no Be star. (b): Frequency distribution of $V_{\rm ZAMS}/V_{\rm min}$ ratios and fit with a Gaussian distribution tail.

References

Denissenkov, P.A., Ivanova, N.S., & Weiss, A. 1999, A&A, 341, 181

Frémat, Y., Zorec, J., Hubert, A.M., & Floquet, M. 2005, A&A, 440, 305

Meynet, G., & Maeder, A. 2000, A&A, 361, 101

Zorec J., Frémat, Y., Cidale, L. 2005, A&A, in press and astro-ph/0509119